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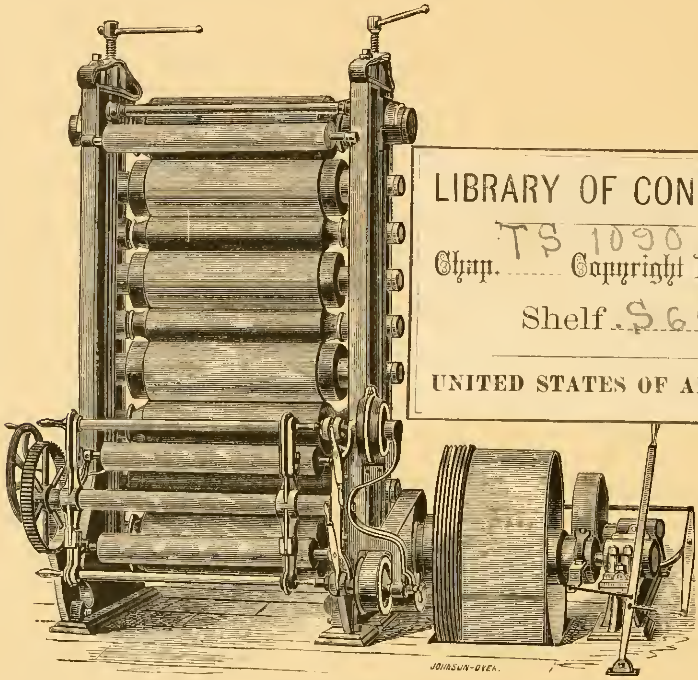

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A HISTORY OF PAPER.

ITS GENESIS

AND

ITS REVELATIONS.

ORIGIN AND MANUFACTURE, UTILITY AND COMMERCIAL VALUE OF AN INDISPENSABLE STAPLE OF THE COMMERCIAL WORLD.

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1882.

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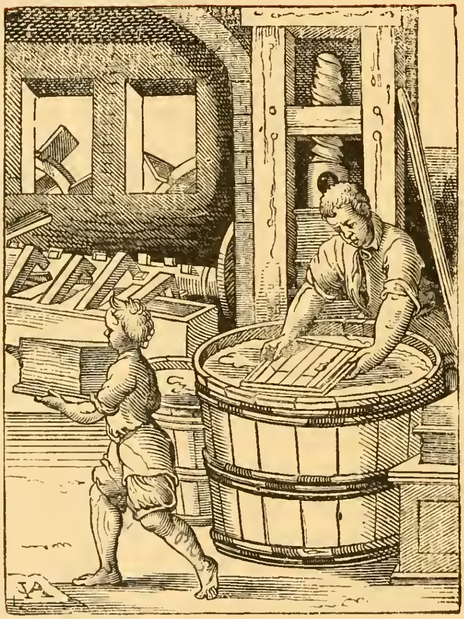

A Sixteenth Century Paper Mill.

IN THREE PARTS.

PART I. Connection between the Invention of Printing and Paper — Reasons for the long delay of both — Articles used in the place of Modern Paper before its invention.

PART II. The Second Era of Paper-Making—Hand-Made Paper from Vegetable Pulp.

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Vat Paper-Making in 1881.

PART I.

Connection between the Invention of Printing and Paper—Reason for the long delay of both —Articles used in the place of Modern Paper before its Invention.

A PHILOSOPHICAL historian maintains that the failure of the civilized and highly cultivated nations of antiquity to invent the art of Printing was due to the lack of a cheap, light and durable material to receive and preserve the impression of the types; and, in support of his proposition, he reminds us of the near and suggestive approach to such a discovery which was constantly before the eyes of Egyptians, Greeks and Romans in the use of seals. Since this proposition was made, some thirty or forty years ago, Oriental investigation has found, antedating even Egyptian civilization, on the inscribed bricks of Babylon and Nineveh, long histories actually printed, although the impression was embossed by moulds instead of being colored by ink. It was, nevertheless, just as much printing as the books which are now prepared for the use of the blind. In often-recurring phrases,

such as the styles of the kings, the inscriptions were doubtless made by stereotyped moulds, but the cuneiform printers upon bricks evidently had movable types, although there is no reason to believe that they learned to compose them in "forms." Each separate character, except in the case before mentioned, was probably inscribed by a mould or type provided with a handle, by which it was deftly taken from a set, which answered the purpose of a modern printer's case, and, after using, as deftly replaced, requiring no further "distribution" before it was again called for. Artists in all such work acquire a dexterity which results in wonderful rapidity of execution, although, of course, immeasurably short of such marvels as are accomplished by our modern machine printing. The motions of the printers or stampers who moulded the old inscribed bricks may be supposed to have been similar to those of the musical Swiss Bell Ringers of our time, although much more rapid, as no rhythmic movement was required.

A still nearer approach to printing in the modern sense is found in the figures and hieroglyphics inscribed, with heated metal brands, by

way of epitaph, upon bands of red leather bound around the foreheads of some of the Egyptian mummies.

It may be added to these suggestive approaches to the invention of printing, that the ancients had, besides the flowing ink used with a reed or quill pen, another which was applied with a stiff brush, and must have been a near approach to printing ink, even if it could not have been actually used as such. Pliny rudely describes it as made, in various ways, from soot, by mixing it with burnt pitch and resins; "for which purpose," he says, "furnaces have been built which do not permit the escape of the smoke. The best made in this way is from pine wood." Soot, obtained in this manner, and resinous oils, are certainly suggestive of lamp and ivory black, resin and vegetable oils; the chief ingredients of modern printing ink.

But, admitting this suggestive approach to the invention of printing—and, as we have shown it, in closer approximation than the author alluded to claims—and granting also that the existence of such a paper as we now possess would have hastened the advent of that art by centuries, still

it does not, of necessity, follow, that its non-existence was the prime or chief cause which, for thousands of years, kept hidden from the world that which is not only "the art preservative of all arts," but the indispensable medium of that new life which, since its discovery, has everywhere been the inspirer of mechanical invention, not less than of other grand results of thought.

We shall find presently that the prepared papyrus of the Egyptians was even more strictly a true paper than the moulded bricks of Babylon and Nineveh were true printing. The real reason why the world remained so many thousand years upon the very verge of two great discoveries without ever crossing it, was that absorption of the mental energy of the nations of antiquity in other directions, which left their inventive genius in a strangely dormant condition. Those nations had artists of wonderful genius and mechanics of admirable skill; but, as compared with those of modern civilization, no great machinists. They were acquainted with the laws of mechanics, and, for some purpose—as in the raising of ponderous stones—employed them with stupendous effect. They had a marvelous dexterity in the use of

artists' and artisans' tools; but, if they ever combined that knowledge and that skill for such purposes as modern inventors and machinists combine them, it was with small result as compared with the simplest modern machinery. Having devised a moderately satisfactory machine—such, for instance, as the hand-loom of seventy-five years ago may represent—they were content therewith. After that, their highest ambition was to acquire a facile use of it, and, at the utmost, to get the best possible work out of it by manual dexterity, without any restless endeavor to improve the machine itself. And this inactivity in mechanic invention—this primitive lethargy of inventive genius—was not confined to the nations of antiquity, but continued throughout the middle ages, and, to a certain degree, even long after the introduction of the paper manufacture and the invention of the printing press. From so protracted a slumber the awakening was naturally slow and gradual. The new philosophy which had birth in the sixteenth century hastened it. The seventeenth and eighteenth centuries witnessed grand and fundamental discoveries and inventions.

But the era in which we now live can hardly be

said to have commenced prior to the year 1880. Grand as many inventions previous to that date were, they did not clearly even prophesy that almost bewildering multiplication of automatic machinery which genius has within the last eighty years endowed with a skill—or at least with a precision, delicacy, rapidity and certainty of execution—never attained by intelligent agents. The powers of machinery, of which previous ages laid the sure foundation, have been carried by ours to an exquisite perfection of which they never dreamed; and that with a celerity of progress compared with which all previous advance was but stagnation.

It is in the light of the truths which we have thus briefly stated that we must read the history of the paper manufacture. And, in order fully to comprehend its worth to the world, we must also first consider the imperfection of the materials which, before its invention, filled its place, and the costly, wearisome and cumbrous processes of their manufacture.

Probably the first purpose for which a substitute for paper was required was the transmission of simple messages; and any tolerably smooth

and light substance which came to hand was sufficient to receive the rude figures or hieroglyphics which told the story or helped the messenger to tell it. The smooth bark or the broad leaves of certain trees were generally most available. The white birch of the American forests would have been a favorite; and it has often been used by both the early settlers and the aborigines as a substitute for paper in cases of necessity.* As the wants of civilization advanced, the different parts of the tree were employed for a time more generally than any other materials; the leaves being strung upon threads for preservation, the outer and inner bark made smooth and so pliant as to be rolled, and the wood cut into thin boards, and sometimes covered with a coating of wax. Thin sheets of metal or of ivory, leather, painted cloth, stones, brick, and every similar material known to that day were also used.

Upon this continent the Aztecs, who attained to a system of hieroglyphical writing, although far inferior to that of the Egyptians, had for their manuscripts, according to Prescott, cotton cloth and skins nicely prepared, and also "a composi-

*An ingenious publisher on the White Mountains printed a newspaper upon birch bark in the year 1880.

tion of silk and gum;" sized silk, as we should say. But "for the most part they used a fine fabric from the leaves of the aloe, *agave Americana*, called by them *magueys*, which grows luxuriantly over all the table-lands of Mexico." "A sort of paper," continues Mr. Prescott, "was made from it, resembling somewhat the Egyptian papyrus, which, when properly dressed and polished, is said to have been more soft and beautiful than parchment. Some of the specimens exhibit their original freshness, and the paintings on them retain their brilliancy of colors. They were sometimes done up in rolls, but more frequently into volumes, of moderate size, in which the paper was shut up like a folding screen, with a tablet of wood at each extremity, that gave the whole, when closed, the appearance of a book. The length of the strips was determined only by convenience. As the pages might be read and referred to separately, this form had obvious advantages over the rolls of the ancients." We have seen Oriental manuscripts of a quite recent date folded in the method thus described.

The ancient Peruvians, who thought the annals of their empire of sufficient importance to require

a corps of keepers, had no better aid to show in the place of paper than the *quipu*—a cord about two feet long composed of different colored threads tightly twisted together, from which a quantity of smaller threads were suspended in the manner of fringe. The threads were tied in knots, and, by their arrangement, indicated not only sensible objects, but abstract ideas. But the *quipus* were chiefly used for arithmetical purposes, which they seem to have answered very well.

Still papyrus and parchment were the two materials which chiefly supplied the place of paper in the civilized nations of antiquity when they came to have an extended literature and large public and private libraries, as well as to require, as we now do, immense quantities for the ordinary transactions of social, official and business life. And these two articles came to be great staples in the commerce of the world; Egypt holding a close monopoly both in the manufacture of the papyrus and in the production of the raw material, which must have been very lucrative indeed.

Papyrus is the Latinized Greek name of a plant called by the Egyptians *Bublos*, whence

came the Greek *Biblion*, paper, and, in a final sense, a book, and thence our name for the Holy Scriptures as the Book of books. It grows in swamps, to the height of ten feet. It was found chiefly in the overflowed lands of the river Nile and the neighboring marshes; but there, in the days of Egypt's prosperity, it grew in immense abundance, being doubtless carefully cultivated and protected. It has now become rare, fulfilling the prophecy of Isaiah: "The paper reeds by the brooks, and everything sown by the brooks, shall wither, be driven away, and be no more." The stalk of this plant, which is properly styled "a reed," is triangular and bare, except near the root, where there are some small leaves. The top is surmounted by a bushy head of long, fibrous foliage, spreading from the stalk very much in the shape of our common feather dust-brush. It was cut annually, about eighteen inches of the lower part of the stalk being sold for edible purposes, and the remainder devoted to the paper manufacture. This stalk consists of twenty pellicles, or thin folds, varying in fineness of texture from the coarse exterior bark, which was only used for cordage and other purposes, for which hemp and

similar materials are now employed, to the coating nearest the pith where the most delicate fiber was found.

The manufactured papyrus was of nine distinct qualities, governed chiefly by the selection of raw material; and it is quite in accordance with modern custom that each was designated by its own peculiar name, as "Augusta," "Liviana," "Hieretica," etc. The last named, originally the best, was reserved for religious books and uses, but, afterwards, under the influence of Roman culture, the others were made to supply its luxurious tastes. The coarsest grades, known as the "Tamoretic" and "Emporetica," were sold by weight, and used only for wrapping paper. The process of manufacture was not complicated as compared either with its results or with the making of modern paper. Neither machinery or any intelligent application of chemical science had any part in it. It was purely a mechanical preparation of a substance wonderfully adapted by nature to the purposes for which it was needed.

The folds in the tissue of the stalk were first separated by an instrument, sometimes called "a needle," and sometimes "a sharp stone." The

latter was probably used at an early period, although we find the same term applied, as late as the middle of the fifth century before our era, to the knife employed in the preparation of bodies for burial.

A layer of one class of these folds was then placed upon an inclined table of wood, wet with the water of the Nile, and the rough ends cut straight. Across this a second layer was laid at right angles, and sometimes a third at right angles with the second. During the reign of the first Claudius over the Roman empire—A. D. 41–54—a great improvement in the fineness, strength and color of some varieties of papyrus paper was made by putting a layer of the most delicate folds over the coarser but stronger. Where the folds were imperfect they were patched, the adhesive power being supplied by a glutinous substance which the Egyptians believed to belong to the Nile water, but which actually resided in the papyrus leaf. The same glutinous quality caused the layers to adhere when they were subjected to the pressure which was the next step in the manufacture. After which they were dried in the sun. A firm, hard sheet having thus been ob-

tained, any roughness in it was beaten smooth with mallets, and the surface polished by hand with a semi-cylinder of stone, glass, shell or ivory.

The width of the papyrus sheet was determined partly by convenience and partly by the length of the papyrus leaf used; specimens are found varying from five to eighteen inches in breadth. The length might be indefinitely prolonged, sheet being added to sheet by the aid of their inherent glutinous property, often aided by paste or some species of glue. There seems to be no good reason why the width might not have been increased in the same way, had it been desirable. When finished, the papyrus paper was rolled upon a wooden cylinder, the ends of which projected, and were often ornamentally finished. The longest roll yet found is thirty feet long and eleven inches wide.

There are many fabulous accounts of the first use of the papyrus as a writing material, as we have described it; but the true date is lost in the mists of the earliest antiquity. In some form it was certainly thus used as early as 2400 B.C. Specimens are still preserved fully three thousand years old. The official papers of those extremely

conservative rulers, the Popes, were written upon it as late as the twelfth century. In this long interval—3500 years—between 2400 B. C. and 1100 A. D., great changes took place in the mode of manufacture—and yet by no means so great in that vast period as the paper manufacture has undergone during the last hundred years. In that fact we have a measure of the comparative rate of progress in mechanical invention in ancient and modern times.

An interesting point in the history of papyrus paper is the part it played in the commerce of the world, which shows both the large quantities manufactured and the culture of the civilization which demanded it. In this connection it is a suggestive fact that the use of papyrus increased when the Greeks obtained possession of Egypt, and both the use increased and the quality improved when Roman domination succeeded to Greek. Its palmiest period was after the Christian era, although for centuries, as well before as after the birth of Christ, it was a most important branch of both manufacture and commerce, the supply being always less than the demand. In the year 15 A. D., a popular commotion arose in Rome on

account of the scarcity of papyrus. In 290 A. D., Firmus, a rich merchant, who in an attempt to reach the throne of the Roman empire captured the city of Alexandria, boasted that among its spoils were so much paper and size that its value would support his army. Early in the sixth century A. D., Theodoric the Great abolished the high tariff upon imported papyrus, and Cassiodorus, a man of letters as well as a Roman senator, wrote a letter congratulating the world on the removal of a tax so injurious to commerce and so unfavorable to the progress of knowledge—a tax upon "an article essentially necessary to the human race" and the general use of which "polishes and immortalizes man."

Memphis seems to have been then, and long previous, the chief seat of the manufacture, for the learned senator speaks of it as "a noble invention of ingenious Memphis—that the beautiful texture made in a single spot should cover all the writing desks of the world." In parts of his letter, which we have not quoted, the style of Senator Cassiodorus displays the flowery bad taste of its day, but the quoted passages sound very much like what a visiting statesman of literary proclivities

might write in our time, referring to the paper manufactures of Lee, Dalton or Holyoke. We might quote further facts showing the great value of papyrus paper in the commerce of the Egyptian, Greek and Roman world, but it is unnecessary. It will not be denied that it held a place, compared with other products, quite as important as paper now does. But, although the chief source of the papyrus plant was in Egypt, it was found elsewhere, in less abundance and in less careful protection; the Egyptian preponderance being similar to that of the southern states of the American Union in the production of cotton.

The papyrus, as a writing material, is naturally about equally durable with modern paper; but two extraneous circumstances have conduced to the preservation of a large number of ancient specimens. Over 2,000 rolls have been found in the excavation of the cities of Herculaneum and Pompeii which were buried in the famous eruption of Mount Vesuvius, A. D., 471; but the greater number have been found enwrapped with mummies in the catacombs of Egypt, and preserved by the exclusion of the air and the antiseptic powers of the substances used in embalm-

ing the dead. The inscriptions upon these rolls are generally in the Egyptian characters, but frequently also in the Greek. They have for the most part the brown color into which ink in which soot is a large ingredient fades, but often the black is as brilliant as though written yesterday.

It is not within our province to discuss the historic or literary value of the writings upon the rolls of papyri which have come down to us, but there is one curious fact that comes within our practical scope. It would have been a bold prophet who dared to tell one of the Pharaohs upon his throne that, in the lapse of ages, and before they had returned to dust, their tombs would be ravaged by their semi-barbarous successors in the land, not only that they might sell to inquisitive students from distant lands, the papyri inscribed with the record of their glories—there might have been some consolation in *that*—but in order to export to regions of which they never dreamed, the linen wrappings in which their embalmed bodies, and those of their people, were so carefully enveloped, there to be used as a material in the manufacture of a better paper than

the Memphis paper-makers ever sent to Rome or Alexandria. And yet it is a fact that the Arabs have plundered the catacombs, disrobed the mummies, and sold their wrappings to be sent to England and America as paper rags. The Egyptian embalmers showed their thrifty habits by using for the inner wrappings second-hand linen, whose darning proves that the housewives of Pharaoh's time were as economical and industrious as ours; but, for all that, the catacombs are a precious linen mine to the Arab and Bedouin rag-gatherers, who even save the more perfectly preserved cloth for their own garments, ghastly as we might suppose the robes to be which, for thousands of years, have shrouded a corpse. These same thrifty modern Egyptians find also, in the catacombs of their predecessors, a rich coal mine, using the wooden mummy cases, and often the mummies themselves, as fuel. Impregnated with the bituminous and other inflammable substances used in embalming, the wood burns like pitch pine and the bodies like cannel coal. A European explorer, not long ago, bought three asses' loads of mummy cases as the only fuel he could procure to cook his food. How prodigious the

number of bodies buried in these caverns must have been may be estimated by the fact, that, after thus being drawn upon for centuries, they still supply the Arabs with articles of sale eagerly bought by Europeans, and also fuel, and sometimes clothing, for themselves.

Is the papyrus—the final product, and not the plant—a true paper? Some good recent writers use expressions from which we can only infer that they so consider it, and yet they often compare it with paper as now made in terms which leave a wide distinction between the two, distinguishing the former as a natural and the latter as a manufactured paper. The writer upon this subject in Knight's Mechanical Dictionary defines paper as "a material made in thin sheets from a pulp of ground rags or other fiber, and used for writing or printing upon or for wrapping." Further on, he gives a fuller definition of "true paper" as "made of rags or other vegetable fiber, reduced to a pulp, gathered into a sheet, felted in setting, and dried." Worcester and Webster, among the uses to which paper may be applied, add to "writing, printing or wrapping," "various other purposes." Webster, correctly as it seems to us, omits the

condition that the pulp must be obtained by grinding rags or other fiber. And although, as we well know, paper, either in its completed state, or in the various stages preceding that, may be, and constantly is, employed for other important purposes than that of a writing or printing material, do we not daily see true paper that can be used for no other purpose than a writing material without a total change in its character? The definition of a thing is strictly the description of that thing as it is, without reference to the process by which it may become so, or any other by which it may be transformed to something else. When we go beyond that we trench upon the province of the encyclopædist, or the essayist. Paper would be paper if we found it growing in leaves upon the trees, as it would be paper still although it could not be, by any pressure, changed into papier mache. We do not mean to say that it is not a uniform and valuable quality of paper as we have it, that it can be so transformed and also used for many purposes aside from its original one, but only that this is not an essential property in its character, not a necessary element in the definition of the word.

We may therefore safely follow Webster in eliminating from the definition of a true paper, the requirement that the pulp from which it is made shall be artificially prepared by grinding, or otherwise. With this variation from the old authorities, the writing material which the old world obtained from the papyrus plant must be recognized as a genuine paper. In the folds of that wonderful reed the old Egyptian paper manufacturers found a pulp sufficient for their purpose and abundantly supplied with a natural size. Beyond that their processes were coincident with our own, however much they differed in the details of their application. To be sure, with all the beating and pressure it received, the original form of the plant's fiber was not destroyed, but, after thousands of years, may be now plainly seen in the earliest specimens of papyri roll extant. But we do not now destroy the fiber of the substance from which we make paper for the sake of destroying it, but because it is necessary in order that it may become a pulp at all, and thus be ready for a new arrangement of its particles.

Paper must be in "thin" sheets. This is a somewhat indefinite requirement. The papyri

were so bulky that a copy of Ovid's Metamorphoses, which in modern print and paper fills only a very small duodecimo volume, covered eighteen papyri rolls, occupying the space upon a library shelf of as many octavo volumes. A copy of the works of Homer, Virgil, Livy, Sallust, or similar authors, would have filled more than ten times as many rolls. And this fact we must take into consideration when we read of the large number of volumes in the Alexandrian and other ancient libraries; for a volume meant simply a roll. And yet the papyri rolls were so flexible that, with some little re-moistening, they may, after their immensely prolonged drying, to-day be rolled and unrolled. They had no such thickness as would exclude them from the list of true papers.

The papyrus was, then, in our estimation, a true paper; while it still, as we shall presently show, differed widely in some respects from the true paper of to-day.

We speak familiarly of paper as being used for various purposes which do not come within the definition we have given; meaning, not that finished paper is so used, but that its fiber in dif-

ferent stages of preparation may be turned to those purposes, as the manufacture of papier mache and other articles which are certainly not "thin," and in this respect the papyrus is its equal, for Herodotus tells us that "the priests wear shoes made of the byblos, the sails of the Egyptian boats are made of the byblos, the priests read to me out of a byblos roll the names of three hundred and thirty kings."

The close affiliation between paper, as we now have it, and the vegetable substances which, with more or less preparation, were, in the early ages, used in its place, is indicated by the modern nomenclature of the paper world. Thus we have paper from *papyrus*, and Bible from the Egyptian name of the same plant. Folio is from the Latin *folium*, a leaf, and we still use it, in its translated form, both for the foliage of a tree and the thin sheets of a book. Page is the Latin *pagina*, a written leaf. Tablets from *tabula*, a board; the the board smeared with wax used by the Greeks and Romans to write upon. Library is from the Latin, *liber*, a book, but previously the inner bark of a tree, from which the material for books was made. It is a happy, but doubtless accidental,

coincidence, that the same word means free, unshackled, independent, open and fresh. Schedule is from *scheda*, the Latin for a strip of papyrus, and afterwards for a sheet of paper. Code and codicil are from *codex*, the trunk or stem of a tree. Volume is from *volumen*, any thing that is rolled or wound up, as sheets of papyrus, and afterwards of parchment, were wound up. In a more liberal sense it was applied to the water which rolls over a fall, and to other rolling and pouring masses. But the first volumes were of papyrus; and each separate roll, as now each bound collection of written or printed leaves, was counted a volume; a fact which one must always bear in mind when he reads of the immense number of volumes in some ancient libraries. It will moderate his wonder why so few names of the books which composed them have come down to us.

We may perhaps as well speak here as elsewhere of the effect which the cheapness and abundance of printed books has had in reducing the use of sculpture upon stone or other enduring material for the preservation of national records. For this, we now trust to the immense

numbers and constant reproduction of printed histories. With this aid, the plain, unsculptured shaft on Bunker Hill tells its story as satisfactorily, and more eloquently, than Cleopatra's needles, with all their wealth of tediously inscribed hieroglyphics, tell the history which they were designed to commemorate.

Parchment, the material most used by the ancients in the place of paper, next to the prepared papyrus, is the general name for the skins of certain animals, when prepared to write upon, and "for other purposes." It is told in the old books that when Eumenes, king of Pergamos, some 200 years B. C., was ambitious to build up a large library, the Ptolemy then ruling in Egypt, jealous of rivalry in that respect, prohibited the export of papyrus, and that Eumenes finally circumvented him and accomplished his purpose by the invention of parchment, which received its Latin name, *pergamena*, from that of his kingdom. If the story is true, the zeal and ingenuity of Eumenes availed him little, for, when Marc Antony was one of the masters of the world, he seized the library of Pergamos and presented it to his brilliant and beautiful but profligate mistress, Cleo-

patra, the Egyptian queen, who added it to that, already famous, at Alexandria, whose fate it eventually shared.

It is, however, quite certain that the skins of animals were among the earliest materials used in the place afterwards filled by paper. Herodotus tells us that the skins of sheep and goats were in common use as a writing material more than two centuries at least before the time of Eumenes, and other writers more obscurely refer to it as in use long before that time. Rev. Dr. Humphrey Prideaux, an eminent philosophical writer in the early part of the seventeenth century, claimed that the authentic copy of "The Law" which Hilkiah found in the Temple and sent to King Josiah, must have been on parchment, as no other writing material could have lasted for the period of 830 years which lay between the writing of that copy of the Law and the reign of Josiah. The intimate relations between the Jews and the Egyptians, and modern discoveries as to the durability of papyrus paper, somewhat impair the force of Dr. Prideaux's reasoning. But we still have no instance of papyrus paper preserved for so long periods, except when buried with cities

or with men, it has been excluded from the air and other destructive agents. And, setting aside all Hebraic story, we still have the authority of Diodorus and Herodotus to the use, long before the time of Eumenes, by Greeks, Romans and Persians, of skins dressed substantially as parchment now is. What may rightly be claimed for Eumenes and those associated with him is, that they made improvements in the manufacture of parchment which better fitted it for use in book-making.

If parchment had a later invention than papyrus paper, it has also had a longer continuance. Fine parchment is now made from the skins of sheep and she-goats, but a better article from those of kids, lambs and young calves; the finest vellum from the skins of still-born calves, kids and lambs. Of the coarser parchments, Knight's Mechanical Dictionary says, with as much truth, and with more wit than is commonly found in encyclopædias—this dictionary being an encyclopædia:

"Coarse parchment for drum heads, etc., is made from calves', wolves', asses' and he-goats' skins. The asses' skin is said to be remarkably sonorous, and it is no wonder, seeing the amount

of noise it has contained at various times. The Greeks found the bones of the ass a superior article for making flutes. The flute and the drum, a rich asinine combination, which probably suggested the Scotch bag-pipe whose drone is nearest to the paternal bray of anything artificial."

In the manufacture of parchment to be written upon, the object was to render the skins thin, pliant, and of a uniform surface, free from fatty matter and other obstacles to its receiving the fluid ink properly. The other qualities having already been in a good measure attained, it was probably the aim and success of Eumenes and his associates to prepare the surface of the parchment to properly "take" the fluid ink and prevent the necessity of recourse to the old paint-like article used with a brush—a much slower and more costly method of writing or copying.

Knight thus describes the modern manufacture of parchment: "After removing the wool, the skin is steeped in lime and then stretched on a wooden frame: its face is then scraped with a half round knife. The next process consists in rubbing the skin, previously sprinkled with powdered chalk or slacked lime, and scraping it with

a knife. It is then rubbed with a lamb skin having the wool on, so as to smooth the surface and raise a very fine nap; after which, if any greasy matter remains, it is again steeped in the lime pit for a few days. The grain surface is then removed with a knife and the skin pumiced, if necessary, to give it an equal thickness."

A peculiarity of the manufacture, not mentioned by Knight, is that the frame, technically "the herse," upon which the skins are stretched, by the best makers, is surrounded by screws, much like the pegs by which the violin is tuned. This is probably a modern invention, the ancients having used a hoop, as the smaller manufacturers now do. But, even with the herse, there is no automatic power, but merely a use of natural mechanical forces applied by hand.

A fine proof of the value of parchment is found in the fact that, during the dark ages, the monks used the rolls containing the great works of antiquity—and which their more enlightened predecessors had treasured up in the monastic libraries—as a material on which to indite their superstitious legends and scholastic controversial essays. Upon the revival of learning, chemical science

found the means to remove the inferior ink of the convents and revive the better, which had been erased. In those curiously restored manuscripts—known as palimpsests—some of the choicest classics have been preserved as perfectly as though they had been hidden in the ashes of Herculaneum or the catacombs of the Ptolemies.

PART II.

The Second Era of Paper Making—Hand-Made Paper from Vegetable Pulp.

It being admitted that the papyri rolls were essentially a true paper, and that parchment is well adapted to some of the purposes for which paper is used, and in some degree to others, it is nevertheless true that the great revolution in the fundamental principles of the manufacture took place when paper was first made of rags, or other vegetable fiber, reduced to a pulp, gathered into a sheet, felted in setting, and dried.

"Human invention," it is said, "had in this case been anticipated by the wasp, which may be considered as a professional paper-maker, devoting a large portion of her time and energies to the production of this fabric, of which she builds her nest. For this purpose she seeks dry wood

—fence rails and weather-beaten boards being a favorite source of supply—which she saws, or rasps, by mastication, into a paste, which, mixed with a natural size exuded for the purpose, she spreads into a sheet in a manner truly marvelous."

As neither the wasp, hornet, or any other insect which operates in a similar manner, ever used its product as a writing material—perhaps from ignorance of the bleaching and polishing processes—we have no means of determining the date when the insect manufacturer began: authorities differ as to the probabilities—all the way from six thousand to six million, or more, years. The date of the invention by man of the art of paper-making from a vegetable pulp, prepared artifically from some vegetable fiber, is somewhat less uncertain, but it varies still over three hundred years in the estimate of different historians. The earliest estimates place it in the reign of Wan-te of the Chinese imperial dynasty, which lasted from the years 179 to 156 before Christ; the latest at about 200 A. D.

So far as we have any information, the Chinese have an undoubted title to the honor of the invention. Four kinds of paper have been made

in China at least ever since the latest of these dates, and it may be that their invention or improvement from time to time caused the diversity of opinions we have mentioned. All these kinds appear to have been known as early as A. D. 250, and to have experienced very little change from that time until the Celestial Empire was recently opened to the influences of our terrestrial civilization. These papers are known as Rice, Silk, Bamboo and Bark.

Rice paper is a material so delicate and filmy that at the first glance one would think it illy adapted to receive writing or printing; but it is much used for those purposes, and we have seen a beautiful little volume composed of it and filled with exquisite paintings of flowers. It is made from the pith of a leguminous plant, which the Chinese import from India and the island of Formosa, where it grows in abundance. The pith, having been prepared of the desired length for the sheet, is cut spirally into a thin slice, which is then flattened, pressed and dried. It obtains its name by receiving a sizing wholly or principally of rice water. The similarity of this process to the preparation of papyrus is so striking

as to render it probable that it was suggested by it.

Bark paper is made from the smaller branches of a variety of the mulberry tree. The bark, after being separated from the stem by boiling in lye, is macerated in water for several days; the outer part scraped off, and the inner boiled and stirred in lye until it separates. It is then washed in a pan or sieve, and worked by the hands into a pulp, which is afterwards spread on a table and beaten fine with a mallet. It is next placed in a tub with an infusion of rice and a root called oreni, and all thoroughly mixed. The sheets are formed by dipping a mould made of strips of bulrushes, confined in a frame into the vat. After moulding, the sheets are laid one upon another with strips of reed between. A board loaded with weights is then laid upon the pile to express the water, and, when that is accomplished, they are separated and dried in the sun. This paper is even more delicate than the rice; so much so that when it is necessary to write on both sides of a page two must be glued together. Supposing, as the natural order seems to suggest, that the rice paper was the first and the bark the

second made by the Chinese, we have here the first appearance of the pulping process in the manufacture. The bamboo paper, made from the fibre of that plant, reduced to a pulp and gathered in films, is, however, very ancient, and possibly older than the bark.

The silk paper is the victim of a misnomer, arising from the misinformation of early travelers, which it has been found almost impossible to correct, for it is commonly believed to be made of silk. Silk is an animal, not a vegetable, substance, and, although a few silken rags or a little refuse silk may occasionally be mixed with other material, they cannot by themselves be reduced to a pulp suitable for making paper. The silk paper of China is made, like our own, from cotton and linen rags, hemp, unmanufactured cotton and the like, sometimes mingled with wood and bamboo pulp and possibly with a little silk. The rags, cotton and hemp, are prepared by being cut and well washed. They are then bleached, and by natural maceration of twelve days' duration converted into a pulp. This is made into balls weighing about four pounds, which, having been saturated with water, are spread upon a frame of

fine reeds and pressed under heavy weights. The drying is completed by suspension of the sheets upon the wall of a proper room; and they are finished by being coated with a gum size, and polished with some smooth, hard substance. The sheets are sometimes of very large dimensions — reaching twelve feet in length with a corresponding breadth, the moulds being managed by the aid of pulleys.

The art of paper-making spread from China throughout Central Asia, and there the Saracens found it during their conquests in Bukhara, about A. D. 704. It is curious, in this connection, to note the method of the paper manufacture as it was found by Moncroft in his travels a little before 1818, in the neighboring region of Thibet:

At a little distance from us, and close to the river, two people are engaged in preparations for making paper. They have two large bags of old paper that has been written upon, manufactured from the bark of the *Latbarua*. A few large flat stones are placed near the edge of the river where a stream has been divided from the main current by a low bank of sods. On the grass are two frames of wood, covered on one side with fine cloth, the other being open, thus forming a shallow tray. The workmen begin by dipping some of the old paper in the water, and then beat it upon a flat stone with a small round one until it is reduced to a pulp. One of the trays is then placed in the broad part of the canal,

leaving a space for the water to run under it. The pulp is then put into a gear pump with water and worked into a fine paste. It is then poured upon the cloth and thus sunk two or three inches in the stream, so that the water rises through the cloth into the tray and still further dilutes the pulp. The floating impurities are picked, and the pulp agitated by hand until it is supposed to be sufficiently clear, when the current of water is lessened. The workman sees if the cloth be equally covered with pulp, and if any spots look thin, he stirs with his finger some other that appears too thickly covered, and raises a cloud of paste which he leads to the thin place, and by making a little eddy with a gradually decreasing motion deposits it there. When the sheet is, by this simple process rendered even, it is raised out of the water and laid upon the ground to dry. After the greater portion of the moisture is extracted it is gradually inclined from its horizontal position, until when nearly dry it becomes upright. When perfectly hard, one corner of the large sheet is lifted from the cloth and then the whole detached by hand.

It is a long way from this primitive process and these rude appliances to the costly modern paper mill filled with complicated machinery and skilled manufacturers. But it is the first step which is half the journey, and the proverbial persistence of the orientals in adhering to old methods renders it probable that the paper-making which, in 1817, Mr. Moncroft found in Thibet was very like that found A. D. 704 by the Arabian conqueror in Bukhara: somewhat

more rude, perhaps, in its appliances, but essentially the same in its operations.

The material for the Bukhara paper is, however, said to have been cotton. At least that was the material used by the Arabians when that enterprising and cultivated people carried the manufacture home. In the eighth century the Saracens made large conquests in Spain, where they established the flourishing Kingdom of Grenada, rich in many arts, among which was that of paper-making for which they at first, probably of necessity, used flax, although in their old Arabian home cotton had been the chief material. Cotton, however, soon resumed its reign. The raw cotton being used, the product was yellow and brittle and the Saracens made little improvement in it. Christian Spaniards, who had learned the art, remedied the difficulty in 1085 A. D., by substituting rags, and the same class, in Xatina, an ancient city of Valencia, in 1151, made the further improvement of stamping the rags, cotton, etc., into pulp, by water power. The paper of this city became famous, and was exported both to the East and the West.

Cotton paper became general about the close

of the twelfth century, but in the fourteenth, having been found as it was then made, not to possess sufficient strength or solidity for many purposes, it was almost entirely superseded by that made of hemp and linen rags; not weakened in their fibre in bleaching as they are in the present mode, which destroys the natural gum. These old linen papers, well sized with gelatine, retain their original qualities in many specimens even to the present day. The manufacture of this class of paper became common in France, Spain and Italy in the fourteenth century. The first German mill was built at Nuremberg, in 1390. There are claims of the existence of a document written upon English linen paper bearing the date of 1320; but the best English authority which we are able to consult believes that the manufacture did not exist there until near the end of the fifteenth century, when the "*Bartolomæus*" of Wynkin de Worde, the father of English typography, (published in 1496) speaks of a superior kind of paper made for that work by Thomas Tate at his mills in Stevenhenge, Hertfordshire. In 1498, Henry VII. gave this mill the munificent subsidy of sixteen shillings

and eight pence, which it does not seem to have survived, for we hear no more of it, although Tate lived until 1514. In 1588, one Spielman, a German, and jeweler to her majesty, Queen Elizabeth, established a mill at Dartford, and got knighted for his enterprise. But, probably owing to the civil wars and the political disturbances connected with them, it was long before the paper manufacture flourished in Great Britain. While France, by the superior quality of her product, was enabled to export it in immense quantities to all the countries of Europe—2,000,000 livres in value in the year 1658 to Holland alone—England was importing almost her entire consumption. In 1663, says one authority, she received paper to the value of £100,000 from Holland alone; evidently, however, the product of France, as according to the same authority the first paper mill in Holland was not built until 1685. So slow was the progress of the manufacture in England that in Anderson's Commercial Dictionary, printed at London in 1826, it is stated that paper was first manufactured in the Kingdom in 1690, and that up to that time she paid £100,000 annually for that

imported from France. In 1690 the war with that country at once cut off this supply and called for high duties upon that received from other sources. Even the prospect of this state of affairs had in the year before rendered paper so dear that printing almost entirely ceased, except for absolutely necessary purposes; and now, in 1690, some French Protestant refugees, who had settled in England began the manufacture of white writing paper—that, then recently, made there being brown. The business did not, however, become general. In 1696 a bill was brought into Parliament to lay a tax of 25 per cent. *ad valorem* upon all imported paper, parchment and vellum, 20 per cent. upon that made in England, and 17 upon that in the hands of dealers for sale. While this bill was pending, one company published a protest in which they stated that there were not above one hundred paper mills in all England, of which none, except their own, made anything except brown, and the coarsest kinds of white, paper. Their own product was worth £8,000 per annum; the others would not average £200; that of all England would not exceed £28,000. All the parchment,

vellum and paste-board made or imported in 1695 was not worth more than £10,000.

The bill nevertheless became a law, and, notwithstanding the slight discrimination in favor of the British manufacture, we are not surprised to learn that in 1713 it had "fallen into decay;" but rather to find that in that year Thomas Watkin, a London stationer, succeeded in reviving it, and soon carried it to high repute and perfection. It increased so that in 1721 the whole quantity of paper made in Great Britain rose to 300,000 reams, or about two-thirds the whole consumption of the realm. The value of that made two years later, in 1723, was estimated at £780,000.

But it was many years still, after this, before the English manufacture acquired an equality with that of the continent of Europe; for it is emphatically stated that James Whatman, who in 1770 established a superior manufacture at Maidstone in Kent, and became celebrated in his art, had first worked as a journeyman in some of the principal paper mills "on the Continent."

After this, the work prospered. In 1799 twenty-four millions pounds of rags, of which over one-third were imported from the Continent,

were made into paper in England, and in 1800 the duty on paper manufactured in the Kingdom was £315,805. Favoring laws and the zeal of the manufacturer had made that change from the statement of the Protest of 1696.

The introduction of the paper manufacture into the British colonies in North America antedated, however, even the era of that protest; and the product seems to have been not of the quality styled "brown," although doubtless, not of the purity which would delight a printer of 1881. Before James Whatman's enterprise was well under way the amount of the paper-making in the colonies was so great as to intensely disgust their remarkably affectionate, cherishing mother beyond the seas.

William Rettinghuysen, whose name anglicized into Rittenhouse, was afterwards rendered famous by his great grandson, David, the mathematician and astronomer, emigrated from Holland among the early settlers of Germantown, Pa., now a suburb of Philadelphia; and we are not sure that the family name will not finally find its chief and most lasting honor in the fact that its first ancestor in America established in 1690 the first

paper mill in America. In this work he was associated with William Bradford, for whose character we must refer the reader to Franklin's Autobiography. The mill was built upon a small stream in Roxborough near Philadelphia, still called Paper-Mill Run. Every household in the northern colonies then made linen from the flax grown as a staple upon almost every farm, and it was used for the purposes for which cotton is now chiefly employed; so that the rags and worn-out articles of this material furnished abundant stock for one mill.

We condense the following statement of the other paper mills in America previous to the year 1800 from Joel Munsell's admirable "Chronology of the Origin and Progress of Paper-Making."

The second mill in America was built in 1710 at Crefeld, now a part of Germantown, by William De Frees, a connection of the Rittenhouse family. In 1697 William Bradford, a rather speculative sort of person, leased his quarter part of the Roxborough mill to William and Nicholas Rittenhouse for ten years, at the annual rent of seven reams of printing paper, ten reams of good writing paper and two reams of blue

paper. In 1724 Bradford applied to the executive council of New York for the exclusive right to make paper in that province for fifteen years. Not getting it he did not have a chance to sell out to some practical manufacturer. It is needless to say that he built no mill himself.

In 1828 William Demees and John Gorgas, who had been apprentices of Rittenhouse, erected the third paper mill in Pennsylvania, and are "said to have made paper resembling tanned asses' skin from a species of rotten stone found in the vicinity, which was prepared for use by being thrown into the fire for a short time." If there is any truth in the story the stone must have been fibrous asbestos, and might have remained in a fire more than a short time without hurting it. In 1854 one Maniere took out a patent in England for making a fire-proof paper out of this substance: but it was known in the time of Pliny. In 1728 the General Court of Massachusetts granted to a company the exclusive right of making paper in the Province for ten years on condition that in the first fifteen months they should make 115 reams of brown paper, and sixty reams of printing paper; the

second year the same with the addition of fifty reams of writing paper, and each year afterwards the same with the further addition of twenty-five reams of *superior* writing paper. The same vice clogged the paper manufacture which for many years retarded the progress of the woolen: each maker, instead of perfecting himself in a single branch of his business, undertook all; the same mill in one case making broadcloths, satinets, cassimeres, etc., and in the other the several classes of paper.

The first paper mill in New England—not then specially a manufacturing section—went into operation at Milton, Massachusetts, in 1730, under the patent granted two years before. The manager was David Henchman, a Boston bookseller, who received some aid from the General Court, and in 1731 exhibited creditable specimens of his work before that august body. The mill was discontinued after a few years from lack of a skilled workman; but it was revived in 1770—a citizen of Boston obtaining for a British soldier stationed there, a furlough long enough for him to put it in operation; a favor which the powers over the water would have hardly approved.

The public interest in this mill is shown by an announcement in the *News Letter* in 1769 that "the bell cart will go through Boston before the end of next month, to collect rags for the paper mill at Milton, when all people who will encourage the paper manufactory may dispose of them;" and the public zeal was spurred by the adding of the following poetic effusion:

> "Rags are as beauties which concealed lie,
> But when in paper how it charms the eye.
> Pray save your rags, new beauties to discover,
> For paper, truly, every one's a lover;
> By the pen and press such knowledge is displayed
> As wouldn't exist if paper was not made.
> Wisdom of things, mysterious, divine,
> Illustriously doth on paper shine."

In 1768 Christopher Leffingwell became the first paper-maker in Connecticut, and established a mill at Norwich, being encouraged by a bounty from the colony of two pence per quire on all good writing paper, and one penny upon all printing and common paper. In 1770 he received this bounty upon 4,020 quires of writing paper and 10,600 of printing paper. The government of the colony, probably considering the industry well established, then withdrew its bounty; but

the country was close upon the era of the Revolution, and it was a mistake to withdraw encouragement from a manufacture which furnished a product so necessary as paper. In this year there were in Pennsylvania, New Jersey and Delaware—then the chief seats of the paper manufacture—forty mills whose product was valued at £100,000, not, probably, the pound sterling, but the colonial pound, worth in Federal currency three dollars, thirty-three and one-third cents. Massachusetts when the Revolution commenced had but three small paper mills, and Rhode Island only one, and that out of repair. Connecticut had at least one, in addition to Leffingwell's; that of Watson and Ledyard at East Hartford, which in 1776 wholly supplied the press of Hartford—then sending out eight thousand copies of newspapers weekly—and also furnished the greater part of the writing paper used in Connecticut and in Western Massachusetts, as well as much of that required in the continental army.

In Southern New York there were in 1776 at least two mills; as Thomas Loosely and Thomas Ems obtained exemption from military service

for a master workman and two attendants for each mill, as indispensable to the prosecution of the business.

Massachusetts, Maryland, South Carolina and other provinces at once took measures to increase the supply, but with no sufficient effect. The paper famine continued to be severe, and what could be procured, generally of the poorest quality; everything like rags being ground up together to make paper, giving it the peculiar tints observable in the publications and manuscripts of the period. Paper sufficiently thin, strong, pliable and inflammable for the making of cartridges was especially scarce. Upon the occupation of the city of Philadelphia by the American army in 1778, paper of this class was called for by proclamation, and searched for by files of soldiers, with small result, the largest quantity being a sermon preached in favor of defensive war during the French and Indian troubles, and printed by Franklin. Twenty-five hundred copies were found in a garret, and employed in making the musket cartridges afterwards used in the battle of Monmouth.

In 1781 the public printer of New York was

unable to obtain paper upon which to print the journal of the Assembly.

After the Revolution, paper mills multiplied, but not so rapidly that there were not until the end of the century frequent periods of great scarcity, sometimes compelling newspaper publishers in certain localities to suspend their issues for a time.

The greatest seat of the paper manufacture in America is now found in the four western counties of Massachusetts, a region full of its mills, and with flourishing cities and towns largely dependent upon it for their prosperity. In the sixth century Cassiodorus wrote: "It is a noble invention of ingenious Memphis that the beautiful texture (papyrus paper) made in a single spot should cover all the writing desks of the world." The world is practically many times larger now than it was in the sixth century, and has a great many more writing desks; and it is certainly a thing of note that the "beautiful textures" made in a single section, circumscribed, and remote from metropolitan centres, not only supply a very large proportion of them, but supply greater needs, of which the sixth century never dreamed.

The pioneer of the manufacture in this region, to which it is now so familiar, was Zenas Crane of Worcester, who in 1799 went "prospecting" through it, on horseback—as most traveling there was then done—in search of a proper location for a paper mill, and finally selected one on the west branch of the Housatonic River in the town of Dalton, Berkshire County. The owner, Martin Chamberlin, was so doubtful of the success of the enterprise that he would only give an oral "permit to build and try it," and after the thing was done gave a deed "for the land with the mill standing thereon."

The mill, afterwards known as "The Old Berkshire," was built in the spring of 1801, by Henry Wiswell and Zenas Crane. As described by Mr. Charles O. Brown, president of the Carson & Brown Company, which now owns the works which have succeeded it, it was a one vat mill with a daily capacity for making 20 "posts" containg 125 sheets of paper each, of "cap" or "folio" size, or a weight of from 100 to 200 pounds. Mr. Crane was the manager, and, in addition, there were required an engineer at $3 a week, a vatman and coucher at $3 each, a lay-boy at 60 cents

and board, a man for general work, and two girls at 75 cents a week each and board The history of the business in Dalton and Berkshire is interesting, but it was recently told in an essay by Lieut-Governor Weston, which was published in The Paper World, and is also too local for our present purpose, except in so far as it illustrates the general progress of the manufacture.

About the time of the building of the Old Berkshire mill, the Fourdrinier machine was invented and although it was several years before it was introduced in American mills and many before the first was employed in Berkshire, it marked a new era in the general manufacture and we suspend our account of particular establishments to note some of the great improvements which had been made previous to this invention.

The first point in the manufacture of paper is like the old recipe for cooking a hare: "First, catch your hare"—First, gather your rags. Very much depends upon the character of the rags, and that very much upon the civilization and refinement of the region in, or the class from which, they are collected. But the method and sources of this supply in themselves form a large subject,

which we pass over here. Sufficient, that there are at least, as sorted by the foreign rag merchants, five different qualities, and that in the mills a still more careful discrimination is desirable. Says Tomlinson, a high English authority: "If rags of different qualities were ground at the same engine the finest and best parts would be ground and carried off before the coarser were sufficiently reduced to make a pulp. In the sorting of rags intended for the manufacture of fine paper, hems and seams are kept apart, and coarse cloth separated from fine. Cloth made of tow must be separated from that made of linen, cloth of hemp from cloth of flax. Even the degree of wear should be attended to, for if rags comparatively new are mixed with those much worn, the one will be reduced to a good pulp while the other is so completely ground up as to pass through the hair strainers, thus occasioning, not only loss of material, but loss of beauty in the paper; for the smooth, velvet softness in some papers may be produced by the finer particles thus carried off. The pulp produced from imperfectly assorted rags has a cloudy appearance, in consequence of some parts being less reduced than

others, and the paper made from it is also cloudy, or thicker in some parts than others, as is evident on holding a sheet up before the light. When it is necessary to mix different qualities of rags in order to produce different qualities of paper, the rags should be ground separately and the various pulps mixed afterwards."

At what time these refinements in the manufacture were severally introduced does not appear; they seem to be the result of the experience of practical workers, like Whatman; a natural and gradual growth, unmarked by sudden transitions. The sorting at the mill is done by women and children. Each sorter stands before a table frame covered at the top with wire cloth of about nine meshes to the square inch. To the frame a long steel blade is attached in a standing position, and the sorter shreds the rags by drawing them across the edge. Sometimes the seams and edges are cut out and sorted by themselves, and sometimes they are ripped open with a sharp, small knife. The long knife attached to the frame was formerly, and is sometimes still in American mills, the ends of broken scythes. A great deal of dust shaken out in this operation

falls through the wire cloth into a receptacle below. The rags, as they are cut and sorted, are thrown into compartments surrounding the table and specially assigned to each class.

In many cases, after unpacking bales of rags it is necessary to partially cleanse them in a duster; that is a rapidly revolving cylinder covered with wire netting and enclosed in a tight box. Much dust, which might otherwise vitiate the air of the sorting room, is thus thrown out. The "stamping" method of pulping rags, of which mention has been made, prevailed before the use of the duster and when there was scant sorting of the rags. It was then the practice to pile the rags in large stone vats and leave them a month or six weeks, with frequent stirring and a constant supply of water, to rot or ferment until the fiber became sufficiently loose to be reduced to pulp by pounding with stampers in wooden mortars. A writer cotemporary with this method thus describes the further process:

"These mortars are cut out in a block of heart of oak, well seasoned, the cavity being of an oval figure about eighteen inches broad, thirty inches long and eighteen or twenty deep, the bottom concave and lined with an iron plate an inch thick, eight inches

broad and thirty long, shaped inward like a mould for a salmon, with the head and tail rounded. In the middle of the mortar is a cavity, beneath the plate, and four or five grooves are cut, forming channels which lead to a hole cut from the bottom of the cavity quite through the block; it is covered by a piece of hair sieve fastened to the inside. This plate is grooved to make teeth, on which the teeth of the hammers act, to cut the rags in pieces. The use of the hair sieve is to prevent anything going out except the foul water. Two hammers work side by side in each mortar, and are lifted alternately by the mill. They are sometimes made, in the same manner as the stampers of an oil mill, to lift perpendicularly. In other mills they are large hammers moving on a center, like a fulling mill, and lifted by cogs upon the mill shaft in the same manner. The mortars are kept constantly supplied with fair water by little troughs, leading from a cistern which is kept full by small buckets affixed to the floats of the water wheel; these when they have raised the water to the top pour it into the cistern in the same manner as the Persian wheel."

This was an ingenious contrivance, as will be seen, and a vast improvement upon the primitive method of hand-beating with mallets or stones; but its operation was tedious, and the result not perfect. It was easily superseded by an invention made in Holland about the year 1759, and hence called the "Dutch Engine," but of late more commonly simply "The Rag Engine." Essentially there are two engines arranged in pairs upon different levels, the bottom of one being higher than

the top of the other, so that the contents of the higher may be let off into the lower; the stuff partially pulped in one becoming completely so in the other. Knight's American Mechanical Dictionary describes them as follows:

"The two are alike in general construction, consisting of an oblong trough with semi-circular ends. They are made of wood lined with lead, or may be entirely of cast-iron. The trough is divided by a longitudinal partition, on one side of which is journaled a revolving cylinder provided with teeth. This cylinder is capable of being raised or lowered, and works against a block fixed in the lower part of the trough, which is also provided with cutters corresponding to those of the cylinder.

The first, or upper machine, is termed the Washer, as into it the rags, after being boiled in lye, are introduced. A current of water is allowed to flow through the trough, and the roller, in its elevated position, is set in motion, which thoroughly washes and cleanses the rags. The roller is then lowered in its bearings and the speed of rotation increased, causing a constant current circularly around the trough, carrying the pulp between the roller and the block until it is reduced to what is technically known as '*half stuff*.' This is then transferred to the second engine, known as the beater. During this part of the process the bleaching material is added. The Beater, or Pulping Engine, is precisely similar to the washer, except that its roller and block are provided with a large number of cutters, and it is driven at higher speed. * * * * The pulp in its finished condition is called '*whole stuff*,' and is run into a reservoir whence it is taken out as it is wanted to supply the vats."

The rag engine is still in use, with some im-

provements, but substantially of the same construction. At first, in Holland, it was driven by wind-mills; in England and America chiefly by water power. Of course steam is now largely employed.

After the rags had been cut and beaten into whole stuff, all the other processes of the manufacture were performed by hand, until about the opening of the present century; the method being that described below:

"The 'whole stuff,' now often called the 'beaten pulp,' prepared in the engine, is run out by pipes into the stuff chest, where, if there are different kinds, they are mixed. It is then transferred to vats or tubs, each of about five feet in diameter and two and a half feet deep, provided at the top with planks inclined inward to prevent slopping during the moulding. In the Old Berkshire mill, and doubtless in others in America, these vats were square and smaller at the bottom than at the top.

The paper is made into sheets by means of *the mould* and *the deckle.* The mould is a shallow box, or frame, firmly made of mahogany, of which the top is covered with a wire cloth or screen, varying in fineness with the paper to be made. It consists of wires tightly stretched across the frame and crossed at right angles by a few stronger wires bound to the smaller at the points of intersection by a still finer wire. In several kinds of paper the marks of the mould are apparent, the fabric being thinner where the pulp comes in contact with the protuberances. It is on the same principle that what, by a misnomer, is called the water-mark, is produced, fine wires bent in the desired form being sewed to the

surface of the mould, and leaving their impression upon the sheet.

The paper moulded upon the kind of wire cloth described above is known as laid. A species of it, or an imitation made by machinery, has since been highly esteemed by connoisseurs as a writing paper, but the roughness it exhibited in the early part of the eighteenth century rendered it objectionable for that purpose, and still more so for printing; which led to the invention in England, about the year 1750, of wove paper; the wire cloth of the mould, not the paper, being woven. The result was a perfectly smooth sheet.

The deckle is a thin, flat frame of mahogany, bound at its corners with brass, corresponding in its outer dimensions to the size of the mould and in its inner to that of the sheet to be moulded. Its office is to retain the pulp upon the wire cloth, and it must be so evenly made that it will lie flat upon it, or the edges of the paper will be badly finished. When the deckle is in place it forms, with the mould, a shallow sieve, not fastened together, but held in place by the two strong hands of the *dipper*, a skilled workman, who takes up in it so much pulp suspended in water as his experience tells him is sufficient for a sheet of paper. This he shakes gently until the water is drained off and the pulp spread evenly upon the wire, in the form of a sheet. He then removes the deckle, and shoves the mould along a board placed for that purpose on the top of the vat, to the *coucher*, another workman, who, with great skill and care, gradually inclines the mould to a piece of felt or woolen cloth laid flat to receive the still soft sheet of pulp which he gently deposits upon it, and returns the mould to the dipper to be again used. By constant practice the two become so dextrous as to repeat this delicate operation with great rapidity, considering its nature, although of course not to be compared with the speed of modern machine work. The dipper thus continues to lay alternately a sheet and a felt until a *post*—that is, six quires—are piled

up; the felt absorbing a portion of the moisture which remains, and preventing the sheets from adhering to each other as they would in their raw state if not separated. When a post is completed it is put in a screw press, which forces out a large quantity of water, hardens and consolidates the paper, and, to a certain extent, smooths the swells and hollows caused in the laid paper by the wires. When a second post is ready, the first is taken out of the screw press by the *lifter*, a third skilled workman, who makes them up into a compact pile without felts. When several of these piles are ready they are put into what is called the wet press, and, under heavy pressure, a great deal of moisture is again expressed, the sheets gain stronger consistency by the closer interlacing of the fibers, and the felt marks are obliterated. After being removed from this press, the sheets, in parcels of seven or eight, are hung to dry upon peculiarly arranged racks. When sufficiently dry the paper is taken down, sleeked, dressed, and shaken to separate the sheets and get rid of the dust. Next comes the sizing—the size being made from the shreds and parings of raw hide and parchment, the liquid product of which is nicely clarified and receives a small modicum of alum. Into this the sheets are dipped in such a manner as to expose both surfaces. The sheets are then piled up, with thin boards interposed at intervals to keep them steady, and are again subjected to pressure in order to get rid of any superfluous size. In this and preceding pressings the force must be applied very gradually and with great care, so as to permit any bubbles of air caught between the sheets to escape without injury to the paper. The paper is then transferred to lofts, and in parcels of two, three, or even more sheets. hung up to dry, care being taken to regulate the temperature and the admission of air. After hanging three or four days, it is taken down and carried to a building called a *saul*, from the French *salle*, or the German *saal*, a hall, where it is examined, finished, and again pressed. The press

used is of extreme power, and paste-board very smooth and hard is placed between the sheets in making writing paper; answering to our calendering process. The best quality of paper was hot-pressed; that is, between every fifty sheets of paste-board a plate of heated iron was interposed. The last pressing is repeated several times, the sheets being as often turned, so that the smoothing may be uniform. The paper is then made into quires and reams, trimmed, and once more pressed."

The above description, which is chiefly condensed from Tomlinson, is that of paper-making by hand in England at a comparatively recent date. The earlier manufacture both there and in America, was, however, very nearly the same, with inferior mechanical appliances, especially in the matter of presses. In the Old Berkshire mill, the first in western Massachusetts, the common screw press was used for many years, the power being applied by a lever made of a bar of stout wood, sometimes twenty feet long. A workman in the mill at the time, now a gentleman in high standing in the community, tells us that he has often seen these levers splintered by the workmen in their efforts to secure an effectual pressure.

The engineer, vat-man (or *dipper*) and coucher performed the same work, substantially in the same manner, as in the English mills. But, in-

stead of the lifter, the lay-boy took the sheets from the felts and laid them in piles, an operation which required some dexterity; and the subsequent processes of pressing, sizing, trimming and folding were done by such work people as were competent and could be spared from other work, under the direction of the overseer or engineer. The lay-boy held a good deal such a position as that of the devil in a printing office. When he was not engaged in his special duty he was kept busy in tending upon the workmen, and on all sorts of errands, the most frequent being to Holden's tavern, to which he was constantly despatched for bottles of rum or some other liquor, for which he was rewarded with a liberal glass upon his return. The gentleman who tells us this from his own experience wonders that this practice did not make him a drunkard. Before he was fourteen years old he had, by it, acquired a love for ardent spirits, which he still retains, although for over forty years he has tasted none.

The reader will observe *passim* the large number of workmen employed in proportion to the amount of product as compared with the modern machine manufacture, and also the low wages of

labor. A considerable number of the skilled workmen employed, probably twenty-five or thirty during the first thirty years, were Englishmen.

A matter of some interest belonging to the era of the hand manufacture is the derivation of the names of certain classes of paper from curious water-marks of the old makers. One of the oldest—as far back as 1539—consisted of a hand pointing to a star; whence came the name of "hand paper." A favorite mark about the same time was a jug or pot, and so came "pot paper." When the Puritans had succeeded in overthrowing the royal government and establishing the English Commonwealth, they substituted for the royal arms, which had before distinguished a certain class of paper, a fool's cap and bells, and from that piece of grim ridicule the "foolscap" sheet took its name. A postman's horn indented upon another size made it "post," and with the addition of the city where it was first made, "Bath post."

PART III.

The Manufacture of Paper by Machinery—The Manufacture of Paper by Hand.

Great as the advance had been from primitive methods, paper-making at the close of the last century was still a tedious, difficult, and therefore costly, operation. But if there was among manufacturers any longing for improvement by means of machinery, it was far from hopeful. They seem to have been resigned to the separate moulding and finishing of each sheet by hand, although it required much time, as well as extraordinary care and skill in each workman from engineer to lay-boy. And yet the first and most important step had been taken towards the invention of a machine by whose aid, chiefly, the process has been rendered so nearly automatic as to require comparatively little care and skill on the

part of subordinate workmen, and so hastened that rags received at the mill on one day may be turned out the next day as paper, instead of requiring three months as formerly; while, although the machine is itself very expensive, the cost of the product is reduced fully one-half. An English writer, speaking of what is accomplished by this machine in mills known to him, says: "In the brief space of *three minutes*, and in the short distance of thirty or forty feet, a continuous stream of fluid pulp is made into paper, dried. polished and cut into sheets. The paper thus produced is moderate in price, and for many purposes superior to that made by hand. It is of uniform thickness, and can be fabricated of any desirable dimensions. It does not require to be sorted, trimmed or hung up in the dry-house—operations which in the hand manufacture led to defects in about one sheet out of every five."

This extreme speed, however, is not usual, nor indeed is the manufacture from the rags in one day very common, although in case of necessity in book and newspaper it is not infrequently done. In the English mills the same may be true of writing paper, which is there completely

finished by machinery. The best American writing papers—known as *loft dried*—after being sized, dried, and cut into sheets, are taken from the racks hung in lofts for complete drying and finished by hand, with the aid of powerful calendering presses. But even these, if need be, can be finished in five days from the rags.

The early history of the machine by which the achievements specified by the English writer are accomplished—and which we now call the Fourdrinier Paper Machine—is a noble one in itself, but sad as regards the men to whom the world is indebted for it—literally indebted; for, except in pitifully scant honors to their names, small part of the debt has ever been cancelled. Most of them died in poverty, to which they were reduced from affluence by their expenditures in this behalf; and in biographical dictionaries which carefully preserve the memories of petty politicians, obscure divines and the like class of "notables," we look in vain for the names of Robert, Gamble, Fourdrinier and Donkin.

It was in the year 1798, when the throes of the French Revolution were beginning to subside under the rule of Napoleon, that Louis Robert,

sometimes called a clerk and sometimes a workman, in the mill of Louis Didot at Essonne, announced that he had invented a machine by which he could, with the aid of one man, make sheets of paper fifty feet long and twelve wide. But he apparently left this incomplete to pass to a more important device in the same direction. He had an ardent passion for invention, and was probably both a clerk and workman. He was ridiculed, and even reproached, for wasting his time and energies in a pursuit which "could never amount to anything;" but he persevered manfully, and soon completed a small working model—"not larger than a bird-organ"—upon which he made endless, or continuous, paper, although not wider than tape. From this model a machine was constructed, which in 1799, at the Essonne mill, made a continuous web of paper, twenty-four inches wide—a size at that time much used in France. The government awarded Robert a patent upon his invention for fifteen years, and a gratuity of 8,000 francs. Shortly afterwards he sold to M. Leger Didot his patent and small working model for 25,000 francs, to be paid in installments; but the payments not being made

according to agreement, he recovered his patent by a decree of court dated June 23, 1801.

The machine operated in 1799 was very imperfect, and the distracted condition of France for many years previous had left neither the wealth of its capitalists nor the skill of its mechanics in a plight to aid in the necessary improvements. In this state of affairs, while the invention was still in the hands of M. Leger Didot, he proposed to his brother-in-law, Mr. John Gamble, an Englishman, to seek the aid of British capital and skill. Gamble assented, and the scheme was carried out, according to one authority, with the permission of the French government for the transfer; which seems hardly probable as, to say nothing of the intense international jealousies of the period, France and England were at that moment engaged in a bitter and critical war. But, at any rate Didot somehow got safely over the Channel, towards the end of the year 1800, and with his small model of Robert's machine, proceeded to London. In the meantime Gamble, who had preceded him, and who held some office under the British government, had succeeded, by his personal influence and by ex-

hibiting long rolls of the paper made at Essonne, in enlisting the sympathies of a firm of wealthy and liberal capitalists, Messrs. Henry and Sealy Fourdrinier, then the leading stationers of London. Thus happy in early obtaining the aid of capital, the adventurers were equally fortunate in the employment of mechanical skill and genius. Dartford in Kent, long noted for the manufacture of paper and paper-making machinery, had in Hall's engineering establishment, all the tools then known which would be required in the improved construction of the novel automaton; and, what was of still more consequence, they found in Mr. Hall's assistant, Bryan Donkin, a young and zealous machinist who combined precision of workmanship with fertility of invention in a remarkable degree. To this gentleman they entrusted the development of the inchoate invention; and in 1803, after almost three years of the most intense application, he produced a self-acting machine for making an endless web of paper, which, being set up at St. Neot's, under the supervision of Mr. Gable, "worked in such a manner as to astonish every spectator."

From that time Mr. Donkin devoted all his

talents and energies to the progressive improvement of "that admirable apparatus," which, in the opinion of Dr. Ure, "has by the unfailing regularity, precision, promptitude and productiveness of its work, earned for him a place along with Watt, Wedgewood and Arkwright, in the temple of mechanical fame." In the year 1851 the firm of Donkin & Co., of which he was the senior partner, made their 191st Fourdrinier machine. They had sold 83 for Great Britain, 23 for France, 46 for Germany, 22 for the north of Europe, 14 for Italy and the south of Europe, 2 for America and 1 for India.

In April, 1801, Mr. Gamble was granted a patent upon the machine as it then was, and in June, 1803, another upon certain improvements, both of which he assigned in 1804 to the Fourdriniers. In 1808 he assigned his whole interest in the concern to the same firm, having lost in the enterprise both his fortune and eight years of irksome diligence. In the meantime, in August, 1807, his patent of fourteen years from April, 1801, was extended by an act of Parliament for seven years longer. The proprietors showed good reason, in the enormous cost of their experi-

ments and the national importance of the invention, why the extension should be fourteen years instead of seven. There was no objection to the longer period in the Commons, nor to its justice in the House of Lords; but the committee of the latter said: "Take seven years now, and if your remuneration does not prove sufficient in that period, come again and you shall have seven more." And so it would have been, but for an unworthy trick of Lord Lauderdale, the sole opponent of the extension, who cunningly got inserted in the rules of the House of Lords, a standing order that no extension of a patent should be granted except to the original inventor. It was in vain represented that Henry Fourdrinier was substantially such.

But even before the expiration of the patent as granted, the generous and enterprising Fourdriniers, who had withdrawn £60,000 from their stationery business to further the invention, became bankrupt; so many difficulties had they encountered, and so little was the aid which they received either from the government or the paper manufacturers of the country they were serving so well. And, not only did they receive no aid, but, after

the bankruptcy, none of their patent dues could be collected, although twelve suits were brought in chancery; "that unscientific judge," Lord Chancellor Tenterden, sustaining certain frivolous and merely technical "objections to their well specified patent." Says Dr. Ure: "The piratical tricks practiced by many considerable paper-makers against the patentees are humiliating to human nature in a civilized, and *soi disant* Christian community. Many of them have owned, since the bankruptcy of the house removed the fear of prosecution, that they owed them from £2,000 to £3,000 each." The Fourdriniers died in poverty; Henry, at the age of ninety, as late as 1855.

In 1806 the patentees claimed that, while it cost sixteen shillings to make a hundred weight of paper by hand, with their machine it could be produced for three shillings and sixpence; so that, there being 900 vats in the United Kingdom, with an annual production of 432,000 cwts., the saving, if the machine were used by all the mills would be £264,000; or more than three-quarters of the entire cost. Subsequent statements of the reduction of cost and increase of production

at various stages in the improvement of the machine give the impression that the sanguine temperament of the patentees led them into some little exaggeration of the probable saving of expense; but the genius of Mr. Donkin soon brought it to surpass what was claimed. Thus, while in 1806 five men were required to tend each machine, in 1813 three sufficed; and these without giving that close attention, or necessarily possessing the same skill which was previously demanded. In 1806 the machine was capable of doing the work of six vats in twelve hours; in 1813 that capacity was doubled, and the expense reduced to one-quarter what it was.

The advantages over hand-making paper claimed in 1813 were: 1st. The superior strength, firmness and appearance of the finished product. 2d. After leaving the machine the paper requires less drying, pressing and pasting, and consequently comes sooner to market. 3d. The quantity of broken paper and re-tree is as nothing compared with what it is in the hand-making. 4th. The machine makes paper with cold water; in hand-making, warm was required. 5th. It is durable and little liable to need repairs. One

that has been in use in Hertfordshire for three years cost only ten pounds annually for repairs. 6th. As paper mills are almost universally run by streams which vary considerably from time to time in their power, an important advantage will arise from the use of the machine. The common mill is limited by the number of its vats, so that no advantage can be taken of the accessions of power which frequently happen in the course of the year; but where the machine is employed, as scarcely any mills are capable of preparing stuff for twelve vats, every accession of power will increase the product without adding to the cost. 7th. The manufacturer can suspend or resume his work at pleasure; and he is, moreover, relieved from the perplexing difficulties and loss consequent upon the perpetual combinations for the increase of wages."

We have given this statement the more fully as, besides its main object, it throws some light upon the state of the manufacture in England during the early part of the 19th century. The price of the machines in 1807, by Donkin's schedule, varied, according to capacity, from £715 to £695 for those driven by belting, and from £750

to £1,040 for those driven by wheels. As each successive improvement simplified the construction, the price was probably at least not increased until larger sizes with attachments for various purposes were introduced.

In the year 1839, two hundred and eighty Fourdrinier machines were working in Great Britain and Ireland, making daily in the aggregate sixteen hundred miles of paper, from four to five feet wide. The invention had lowered the price of paper fifty per cent. and added £400,000 to the revenues of the United Kingdom; and, yet, in the multitude of pensions which flowed from the British treasury to all sorts of persons, worthy and unworthy, we cannot learn that any went to relieve the poverty of Henry or Sealy Fourdrinier. It is not republics alone which are notably ungrateful.

Some improvements have been made in the Fourdrinier machine since 1813, and several most valuable inventions have been added to, or incorporated in it. In the original construction of the machine, the lateral shaking given to the wire web injured the fabric of the pulp by bringing its fibres more closely together breadthwise

than lengthwise, which tended to produce long ribs in the surface of the paper. In 1828 George Dickinson, an English paper-maker, devised a mode of obviating this by giving an up and down motion. But Mr. Donkin introduced a method of governing the vibrations "in a much more mechanical way," which seems to be the slice; a thin blade of steel, which crosses the wire web a short distance from the point where the beaten pulp first reaches it, at a height of about an inch and a half from its surface. All the "stuff" must pass under this, and when it emerges the surface is not only freed from lumps, but the longitudinal waves previously very perceptible have nearly or quite disappeared, and are not reproduced, the motion imparted to the semi-liquid pulp being rather of a shivery character. But the greatest difficulty in the use of the machine, as first constructed, was to remove the water from the pulp and condense it with sufficient rapidity to prevent it becoming *water galled*, and permit the web to proceed directly to the drying cylinders. In 1830 John Wilks, a partner of Bryan Donkin, remedied this by adding a perforated and channeled roller, called a

dandy, which facilitates the escape of the water at this stage in the progress of the web.

In the same year Thomas Barrett, another Englishman, invented a method of introducing the water-mark in continuous paper, by means of engraved plates of thin metal attached to the surface of the "dandy." "It is to this ingenious man," says Munsell, "that we are also indebted for the improved means of finishing paper, owing to the perfection he attained in making cast-iron rollers more true than was possible by the old mode of turning them in a lathe. His method, which is now adopted in finishing all rollers requiring great accuracy, consists in grinding the rollers together for many weeks, merely allowing a small stream of water to run over them without emery or other grinding material.

In 1830, Richard Ibotsford, an Englishman, invented an apparatus for separating the knots from paper stuff, which the sieves or strainers in use could not do effectually. It was previously necessary, both in hand and machine making, to pick lumps from the paper after it was made, which left it often in a damaged state, and still did not entirely free it from imperfections which

were liable to seriously damage type and wood cuts. In 1821, T. B. Crompton, still another Englishman, took out a patent for drying and finishing paper by means of a cloth against heated cylinders, and also for the application of shears to cut the paper into suitable lengths as it issues from the machine. In 1831, Edward Pine of Troy, N. Y., and E. N. Fourdrinier patented a very ingenious apparatus for cutting continuous paper into lengths.

The above and other inventions, made since 1813, have been, or may be, applied to the Fourdrinier machine, of which a fine specimen built about 1876, by George Bertram of Edinburgh, is thus described in Knight's *American Mechanical Dictionary*: "It is of the class known as an eighty-inch machine—that is, the endless wire web upon which the pulp flows, is eighty inches wide and thirty-three feet long; being capable of forming paper over six feet wide, after the edges are trimmed, and of indefinite length. The machine is sixty-eight feet long." The largest made by Donkin in the year 1806 was about thirty feet long, and made paper only fifty-four inches wide.

The operation of the Bertram machine is thus described:

The pulp—(whole stuff) from the heating cylinder is admitted to the receptacle, denominated a *chest*, through a strainer, which consists of a sheet of metal perforated with slits. It is here constantly agitated by a *stirrer*—or revolving frame—and is then driven in a stream into a second and smaller chamber, where it is again stirred by a similar agitator. After passing over a channeled plate, by which extraneous matters of greater specific gravity than the pulp are arrested, it is then delivered on to the endless wire web or apron, which answers to the mould of the hand manufacturer. To this the lateral, or sidewise shaking movement is given,—in imitation also of the hand-maker,—in order to distribute the fluid pulp evenly over the surface. This wire web is supported by a large number of small rollers. The width of the paper is governed by deckle straps,—answering to the deckle frame of the hand manufacturer, which are carried by rollers, their tension being regulated by a peculiar device. Next, a vacuum box from which the air is partially exhausted by a set of air

pumps, withdraws a portion of the moisture from the sheet as it passes over it. The sheet is then carried, still on the wire apron between cloth-covered rollers, by the lower one of which, and others specially provided, the apron returns to the point from which it started, to receive a fresh supply of pulp, and again pursue its round. The paper sheet, parting from the apron, is transferred to a felt blanket, which conveys it to the press rolls. These are solid, and over the upper one is a thin edge-bar, which removes adhering particles of the fiber from the roll, and also serves to arrest the progress of the paper should it stick to the roll, thus preventing injury to the blanket. These rolls are adjusted in their bearings by a screw, so as to exert greater or less power, as may be desired. The blanket then conveys the sheet to a position where it is received by a second set of press-rollers, which farther compress it, and expel more of its moisture. After passing the press rolls, the paper is received upon a second endless blanket, which carries it to the first of a series of steam-heated cylinders, between which it is partially dried and then conveyed between other pressure rollers to

a second set of drying cylinders. Thence, after being subjected successively to the pressing and stretching action of a series of rollers, it is delivered on to a cylindrical reel. Registering mechanism indicates when the proper quantity has thus been delivered; when the reel is removed and a new one substituted.

In modern machine-paper-making there are some variations from old methods in the processes, both before the pulp reaches the machine and after the paper leaves it in an unfinished state; some of which we enumerate.

Two kinds of sizing are used, vegetable and animal; both generally made in the mill. Formerly animal size, or gelatine, was employed exclusively; but when mixed with the pulp in the vat, it was found to injure the felt with which it came in contact in subsequent stages of manufacture, and also the paper, and in 1827, Canson Brothers, in France, patented a substitute, the base of which was wax; and in the same year, M. Delcambre produced another, the base being rosin, to which powdered alum was added. This last is the vegetable size now used, and when prepared, it closely resembles mustard prepared for

the table. Gelatine continues to be used as an animal size, and is still made from the shreds of parchment and raw hide, chiefly the latter. Before it is dissolved for the size bath, it is a beautiful light amber-colored jelly, and cannot be distinguished either by the eye or the taste from the table luxury known as "calves' foot jelly;" indeed, it is essentially the same thing, and properly flavored, is often served up under that name by high-toned caterers to unsuspecting epicures. While the paper manufacture was of small extent in America, the shreds of hide from which the gelatine is made were furnished by the native tanneries, now they are chiefly imported, although there seems no sufficient reason for it. The vegetable size is mixed with the pulp in the vat, when it is intended for printing paper, and sometimes, when it is desired to make a specially hard writing paper. It thus becomes thoroughly mixed with the fiber. This is all the sizing required for printing paper. When writing paper is made, no size is ordinarily mixed with the pulp; but in the special cases, when it is so mixed, an exterior coating of gelatine is afterwards applied.

Some improvements have also been made in the rag engines so that they stand more firmly, and are more neatly made, and also more freely discharge the water. Mr. E. D. Jones, of Pittsfield, has patented valuable devices for the more easy, convenient and satisfactory elevation and depression of the cutting cylinder, (or rolls) and for other purposes connected with the same. Mr. Jones has also patented an improved washer, and a back fall which enables the machine to turn the stuff more rapidly without overflowing. Messrs. Smith, Winchester & Co., of South Windham, Connecticut, manufacture the Jordan beating engine for the purpose of cleaning stuff after it has been three-quarters beaten, which is said to work so perfectly that nothing can pass through it without being brushed.

The water for the rag engines must be of the purest quality, and is now generally supplied from springs, through pipes, and a hydrant furnished with a stop cock. Some of these springs furnish an immense amount of water. Pumps have been invented for the transfer of half stuff, and for similar purposes; and a fan pump for various purposes, but particularly for conveying

back the water which passes through the wire on the Fourdrinier machine. Indeed there is no end to the devices which have been invented to perfect the engines and the machine, and facilitate their working. We have enumerated merely a few, which seem to work a decided change in some important portions of the manufacture.

Printing paper is finished when it has passed the drying cylinders last spoken of in the description of the machine, and it is there cut into sheets by the shears.

In the further finishing of writing paper, the common English and the common American practice differ. In the English mills, the gelatinous sizing, the subsequent drying, the cutting into sheets, the calendering and the folding, are all done automatically by machines attached to the Fourdrinier, through which the paper successively passes without aid from the workmen. This gives rapid work, but the product is not considered absolutely perfect, and it is probably for this reason, that some hand-making establishments still exist in great Britain. The American manufacturers, endeavoring to combine the advantages of the old and the new methods, remove

the damp paper from the machine, after it has passed through a bath of gelatinous size and been cut into sheets. It is then taken to lofts and dried as in hand-making. After hanging about three days, it is taken to a room answering to the *saul* of the hand-makers, and after examination is calendered, each sheet being passed separately by hand between iron rollers which subject it to an immense pressure. It is then folded, packed in quires and reams, and goes to market.

The early process of finishing paper by pressure between sheets of polished paste-board—made in the mill—was superseded by calendering paper, the sheets being placed between copper-plates and passed several times through powerful iron rollers, the product being sometimes called copper-plate paper. This method continued in use until quite recently, but now has given place to what is called super-sheet calendering, in which the paper is passed between rollers, one of which is made of chilled iron, and the other of compressed paper, surrounding an iron shaft. The paper is of the strongest kind—commonly manilla—and is compressed by immense hydraulic power.

THE AMERICAN LOFT-DRIED PAPER OF COMMERCE.

Of this there are many qualities, depending upon the raw material used, the management and machinery of individual mills, and other circumstances; but, as a class, it has no superior. This could have been said of it for years past in regard to the ordinary purposes of paper; but for the uses of luxury, and for what are known as wedding goods, paper was, until quite recently, imported: now the very choicest article of this class, known as plate paper, is made in America. In this, the stock is most carefully selected, every process of the manufacture sedulously watched, and in the calendering a press much more powerful even than that commonly used, is employed, while in it the sheets are placed between plates of polished zinc. The press used for this purpose, in the mill of Z. Crane, Jr., and Brother, at Dalton, exerts a force equal to 330 tons weight. The result is an exquisitely finished surface, rivaling satin or ivory in beauty.

The cost of the machinery required in the immense establishments which fill the place of the little one or two vat mills of seventy or eighty years ago (or in America fifty years ago), may be

partly estimated by that of some of the leading articles: Thus, a Fourdrinier machine of the very first class in size and workmanship, is worth $12,000, from which the price decreases to perhaps $7,000; the rag engines, of which there are necessarily several to each machine, from $1,000 to $2,000 each; the calendering machines from $500 to $1,000; the plating machines, from $600 to $1,400 each.

The Fourdrinier machine made its way slowly at first, except in the British Empire. It was not until the year 1815, that the invention of Louis Robert returned to its birth-place, with the various improvements made in it by English skill, capital and persistence; and the first Fourdrinier machine was made in France. In 1820 it was first introduced into the United States, one of English manufacture being placed in Gilpin's mill, on the Brandywine. In 1828 there were "a number of these machines in the country, of which six—one to every ten mills—were in Massachusetts."

The first Fourdrinier machines manufactured in America, were built about the year 1830, by Messrs. Phelps & Spofford at Windham, Con-

necticut, at which time, or a little before, a great impetus seems to have been given to the paper business of the country, as is illustrated by a statement of the New York *Journal of Commerce*, that although the dimensions of its sheet had been quadrupled in the preceding five years, the improvements in paper machinery had been so great that the cost was reduced 25 per cent.

Whether this gain was made through the Fourdrinier or a rival machine, may be doubted. In 1809, John Dickinson, an English manufacturer, patented a machine to which he afterwards added valuable improvements, which makes a continuous web upon a different principle from that of Fourdrinier, the paper being excellent, especially for printing purposes. In this machine, a hollow polished brass cylinder, perforated with holes or slits, and covered with wire cloth, takes the place of the endless wire web of the Fourdrinier. In the cylinder the air is exhausted through the trunnions or axes of the machine. The Dickinson machine was introduced in the American mills before the Fourdrinier, and appears to have been a favorite. Owing to its cheapness, it is still much used for making straw

and other inferior classes of paper. In 1872, when there were 299 Fourdrinier machines running in the United States, there were 689 cylinder machines.

In 1822, John Ames, son and successor of David Ames, who established himself as a paper-maker in Springfield, Massachusetts, some years before Zenas Crane located at Dalton, produced a cylinder machine which, it was thought, would have a great success. To what extent it was actually introduced, we cannot say. Between 1822 and 1837, Mr. Ames took out four other patents for improvements in paper-making machinery.

Later inventions of paper-making machines seem to have been aimed at cheapness of construction, or at making thicker paper by means of a double web. Scanlan's machine, with the latter object, combines the Fourdrinier and the cylinder, and the outer and inner surface may be of different texture and colors. James Harper of New Haven has an invention for the same purpose which is claimed to have advantages over every other. The Harris machine is also a double web.

The rags and other material from which paper is made, form a very large item of its cost. The gathering of these from the scattered families of the country by tin peddlers and others, which has been continued to this day, furnished a supply sufficient for the manufacture in its infancy; the prizes of bright tin ware teaching the economy of saving them better, perhaps, than money. How much the quaint appeals, in prose and verse, of the manufacturers and newspaper editors, "begging the ladies to save their rags" had to do with the lesson, we can only guess. But with the growth of the manufacture, the home supply soon became inadequate, and great quantities of rags have long been annually imported, as will appear in statistics to be given in the closing portion of this book. They are drawn from all countries in the old world, except those having large paper industries of their own, which are obliged themselves to import. If men have not robbed the cradle to supply this demand, they certainly have the grave, for, as we have said in another connection, the catacombs of Egypt have been ravaged to sell the linen cerements of the mummies to the rag dealers. But with even this

aid, the supply became limited and rags rose in price. The demand for substitutes began early in the present century, and the search for them has continued ever since. Knight's Dictionary prints, in Nonpareil type, a list of the articles which have been used or suggested, and if it were in a continuous column it would measure forty-six inches. Those who have read the first section of this book need not be told that the use of wood, reeds and the like substance as a material for paper, is not a thing of recent centuries in the world, whatever it may be in Europe and America. However, a good many things have to be discovered more than once in this wide world, and new methods of better doing the old work go on forever. And thus in the year 1800, the Marquis of Salisbury presented to our old friend, King George III., who had such a repugnance to paper-making in America, a book printed upon paper made of straw. We have little doubt that the paper was made and the book written by Matthias Koops, who, in 1801, "succeeded in making the most perfect paper from straw, wood and other vegetables, without the addition of any other known paper stuff."

He printed a book upon the fabric from these materials, and concerning them, from which Munsell gathered many facts for his Chronology. During a rag famine in Germany, in 1756, an attempt was made to use straw in the paper manufacture, and a book was published giving a plan for reducing all vegetables to pulp. Probably Koops, who, from his name, appears to have been at least of German decent, had seen or heard of it. " He seems also to have been the first to discover a mode of extracting printing and writing ink from waste paper. He obtained a patent for manufacturing paper from straw, hay, thistles, waste and refuse hemp and flax, and different kinds of wood, fit for printing and almost all other purposes for which paper is used. He claimed to have produced the first useful paper that had ever been made from straw alone." But rag famines were at that time rare, and little if any use was made of Koops' discovery.

In 1824, Louis Lambert, a Frenchman, took out a patent for an improved method of reducing straw to pulp and extracting the coloring and other deleterious matter, so that it could be used

in the ordinary rag engine. In 1827, Wm. Magaw of Meadville, Pa., patented a mode of preparing hay, straw, and similar substances for making paper. The product was said to be yellowish, but even and strong, and to receive ink as well as common writing paper. Paper was made under this patent at Chambersburg, Pa., in 1828, and it was stated in the newspapers that machinery was being constructed to make 300 reams of it a day. Louis Bomeisler of Philadelphia, in 1829, obtained a patent for making straw writing paper, white and handsome.

For bluing and bleaching paper Smalts were used exclusively until 1840. At that time some paper-makers in Germany and at Annanay, in France, tried to substitute Ultramarine, on account of its being cheaper and offering less difficulties in its application. They were not successful however, as it did not resist the action of the alum. Artificial Ultramarine was discovered in 1827–28, by Woehler, in Germany, and Guimet, in France, and was first sold at about $4 a pound, while natural Ultramarine obtained from Lapis Lazuli, was selling at $80 per pound. About 1852 a few manufacturers succeeded in preparing

alum proof Ultramarine, which came quickly into general use for bluing, and more particularly for bleaching or whitening paper. There is no other substance nor process known that will give the paper a more permanent and softer whiteness, or a more durable blue tint.

The process of making alum proof Ultramarine is as yet only known to a limited number of manufacturers. All attempts to produce it in this country failed, until a few years ago, the firm of Hoffman & Kiessig of New York, commenced to turn out an article which compares most favorably with the best known German and French brands, and finds a ready sale. Blue Anilines are used as a substitute for Ultramarine on book and news,—mostly cheap goods,—but scarcely on writing paper. While they have high coloring qualities, they lack bleaching power, and above all, fastness of color. For a while Aniline took, to some extent, the place of Ultramarine, but time having shown how quickly it fades, it is now used less. It is used to best advantage where the pulp has been first whitened with Ultramarine. The process observed in applying the Ultramarine is as follows:

Before putting it into the engine, it is separately dissolved, 1 pound of Ultramarine in one quart of warm water. To avoid spots, an ounce of Soda Ash is added for every pound used of Ultramarine.

In all colors where Ultramarine is used for whitening it is put in by itself; the second color is dissolved separately in boiling water, put in boiling hot, and dashed off with cold water. By this method a very brilliant hue is obtained. A great variety of beautiful and lasting green shades, particularly in writing paper, are obtained with Ultramarine through a combination with chrome yellow.

In 1854 a practical chemist exhibited in New York a superior quality of paper made entirely from straw and other grasses, claiming to have discovered a process of freeing them from their silex and other detrimental substances. In 1855 the Saratoga *Whig* was printed upon paper made three-fourths of straw, by Buchanan & Kilman of Rock City, who employed a French Bleaching process and made a good writing and printing article. Improvements continued to be made and the manufacture extended, until, in 1870,

when superfine book paper ruled at 20 to 24 cents, and fine book paper at 16 to 17 cents, the newspapers were mostly supplied with straw paper at from 12 to 12½ cents. The manufacture of paper from wood reduced to a pulp has not been so rapid, or extended so widely as that from straw, but excellent rĕsults have been obtained, and a large quantity of the pulp is now annually used.

We give some statistics from Appleton showing, to some extent, the growth of the paper manufacture in the United States since the period of which we have already given the facts:

In 1810 the number of mills in the United States was estimated at 185, of which 7 were in New Hampshire, 38 in Massachusetts, 4 in Rhode Island, 17 in Connecticut, 9 in Vermont, 28 in New York, 60 in Pennsylvania, 4 in Delaware, 3 in Maryland, 4 in Virginia, 1 in South Carolina, 6 in Kentucky and 4 in Tennessee. They produced annually 50,000 reams of newspaper, valued at $3.00 per ream; 70,000 reams of book paper at $3.50; 111,000 reams of writing paper at $3.00, and 100,000 reams of wrapping paper at 85 cents.

In 1828 the newspapers consumed 104,400 reams, costing $500,000, and the total value of all the paper made was nearly $7,000,000, and of the rags and other materials used about $2,000,000. In 1839 and 1840, the value of the rags imported each year was $560,000, of paper imported, $150,000, and of paper exported, $85,000. In 1850 the value of rags imported was $748,707, three-quarters coming from Austrian and Italian ports, at a cost of $3.16 per hundred pounds. The imports of paper in the same year amounted to $496,593. The capital invested in the manufacture in the United States was about $18,000,000, and the annual product of paper about $17,000,000. In 1870 there were, in the United States, exclusive of paper-hanging manufactories, 669 establishments, mainly making printing, writing and wrapping paper, with a capital of $34,365,014, and products valued at $48,676,985. Of those, 117 in New York produced $10,301,563; sixty-five in Massachusetts, $6,661,886; seventy-five in Pennsylvania, $5,176,646; forty-three in Ohio, $3,799,505, and sixty in Connecticut, $2,715,630.

In Sept., 1882, the number of paper and pulp

mills in the United States was 1040. Since 1870 the expansion of the paper industry has been very great, especially in Massachusetts. In the very latest years many new mills have sprung up in the West.

We have thus attempted to trace the story of one of the grandest and most important of the industries of civilization, from the earliest years of the earliest nations to the latest year of the youngest. In this space at our command, we could not be expected to treat so large a subject profoundly, or to exhaust it; but we have endeavored to give some correct notice of it, and if we have approximately succeeded, it was worth the endeavor.